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INTEGRATIVE APPROACH TO THE CURRICULUM AND CONTENT DESIGN FOR THE PRE-SERVICE TEACHERS' TRAINING

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Abstract

Various approaches to the curriculum and education content development are permanently in focus of didactic research and practice of specialists' training. It is obvious that the subjects which actually make vocational curriculum, their structure and interaction, have powerful influence on the pre-service specialists' professional expertise. According to recent studies, integrative approach to creation of interdisciplinary curriculum is taking on real significance. The issue has special importance for pre-service teachers' training. Their integrated knowledge and skills must enable to render the same approach to their professional activity directed on schoolchildren. Thus, the objective of the paper is to represent author's technology of integrated curriculum design based on scientific knowledge penetration and application of AI tools, and the analysis of its influence on the outcome of pre-service teachers' preparation. Methodology of diagnostics of trainees' features is elaborated and applied. Special focus is made on the process of picking up interdisciplinary learning activity supported by the obtained integrated content. Future scope may include application of the proposed integrative approach to defining curriculum systems and solving various didactic problems.

Keywords

Pre-service Teachers' Training, Integrated Curriculum Design, Scientific Knowledge Penetration, Interdisciplinary Learning Activity

1. Introduction

Recognizing importance, complication and controversial character of complex processes in state-of-the-art society, it is relevant to emphasize increasing demands and challenges to contemporary education. According to recent studies (Boskovic, 2016; Jun-yin & Jing-qing, 2013; Jung, 2015; Lupu, 2015; Voronina, 2018), among requirements to university graduators of different vocations there are abilities to integrate all aspects of knowledge, to apply their compound skills to related areas, to re-train flexibly on changeable conditions. Along with the requirements, it is also pointed out the objective growth of amount of knowledge and its diversification, which complicates the process of forming students' concentrated and coherent system of vocational knowledge and skills.

Under the circumstances exposed above, pre-service teacher's training must respond to contemporary social challenges and provide the society with high quality teachers who have both the relevant competence in their area (content knowledge) and knowledge of curriculum development. It means that to teach schoolchildren meeting nowadays standards, teachers have to understand discipline matter flexibly and deeply in order to help their pupils create efficient cognitive nets, relate ideas and concepts, realize how they connect across academic subjects and daily life. As a result, it provides a base for pedagogical content knowledge helping teachers to make subject matter accessible to others. Moreover, it is really crucial for good teaching to provide the system of didactic activities (comprehension, transformation, instruction, evaluation, reflection etc.), which should be done minding integrative potential of the subject. So, all this requires special attention to the process of content design at vocational training of secondary school teachers.

The content of vocational education is implemented with the system of curriculum subjects. Hence, it is really important to create the consentient complex of the disciplines that are structured, minding adequate connections between components of knowledge. At the same time, any academic discipline is an educational adaptation of respective scientific branch(es). So, it has to render the structure of knowledge domain in proper way, and preserving essential connections across the components of the specific scientific branch and across sciences due to the objective integrative processes which permanently take place in science and society. Thus, structured and taught in proper way, academic subjects may make for the formation of trainee's holistic supple system of knowledge and skills. In the context of teacher's training it sounds even more important as it expects their formed ability to promote making of such a system in their potential students' minds.

There are some well-known approaches to the disciplines structuring. According to recent research, the modular structuring of curriculum subjects (common for European university education) without preserving and conveying proper connections between scientific knowledge may lead to the set of fallouts: destroying links between related subjects, ruining logic and wholeness of a discipline, and, as a result, forming of uncoordinated system of trainees' knowledge based on contradictory and fragmented ideas, etc. (Clark & Linn, 2012; Clark & Linn, 2003; diSessa, Gillespie & Esterly, 2004).

It is also pointed out in the studies (in particular, Renzi, Sangiorgio, & Carrada, 2013; Singh & Kumar, (2017) and others) that nowadays we should develop alternative approaches to curricula design on all levels of education to overcome the exposed problems, to cultivate interdisciplinary strategies of teaching and learning, to focus students on the study of relationships between elements of knowledge and forming their compound skills.

Thus, based on considerations described above, the principal objectives of the study were as follows: (1) to determine procedures for scientific knowledge integration in the university curriculum; (2) to develop technology of the procedures realization in the process of curriculum subjects structuring and interdisciplinary curriculum development; (3) to verify the technology and investigate its impact on the results of pre-service teachers' training.

2. Theoretical Framework

2.1 Procedures for scientific knowledge integration in the university curriculum

The phenomenon of cross-functional knowledge integration is widely discussed by researchers in various branches. In particular, according to analysis of wide range of sources, it is considered as a core issue in the branches of organizations management; product development projects; building and maintaining knowledge-based systems of Artificial Intelligence.

In the context of educational processes knowledge integration is investigated by the researchers from the standpoint of various aspects. For instance, it is underlined the importance of knowledge integration for building students' coherent knowledge structure (Clark, D'Angelo, & Schleigh, 2011; Fodor & Pylyshyn, 1988 and others). The links between knowledge integration and curriculum design are pointed out in (Clark & Linn, 2003; Drake & Burns, 2004; Linn, Eylon & Davis, 2004). Approaches to knowledge integration promotion at learning science by graduate students are provided, in particular, by (Linn & Eylon, 2011) who elaborated special physics teachers program focusing on knowledge integration tasks.

According to pedagogical studies, knowledge integration is mostly understood as the process by which students set up links between new and existing concepts to achieve more consistent understanding of science (Liu, Lee, Hofstetter, & Linn, 2008). Knowledge integration is considered also to be the ability to apply theory or evidence to create students' connected and consistent reasons (Nichols & Sugrue, 1999; Shepard, 2000 and others). It is in particular emphasized by the researchers that creating links and forming arguments leads to more organized realizing of the scientific notions and essential connections between them (Lee, Liu, & Linn, 2011). In addition, it is pointed out (Fodor & Pylyshyn, 1988) that knowledge integration is necessary to form a coherent concept representation in the learner's brain. The representation gives the learner opportunity to accept and apply the concept to exploration and problem solving in different ways.

In our research we focused on the understanding of exactly scientific knowledge integration. Basing on different research (Agar, 2012; Agassi, 2007; Kuhn, 1996; Lakatos, 1978; McDonald & Czerniak, 1994; Rousseau & Roy, 1980), we retrospectively investigated the integrative processes in scientific branches, their reflection in academic subjects and, respectively, in the university curriculum design. As a result, in order to develop integrative approach to the discipline structuring and creating interdisciplinary coordinated curriculum exactly for pre-service teachers' training, we formulated some core theses presented below.

Firstly, integration of scientific knowledge as a phenomenon is a mutual knowledge infiltration throughout scientific branches. It results in the emergence of knowledge with higher capacity for information.

Secondly, integrative tendencies in science development strongly influence on the process of knowledge building in two main ways. On the one hand, advanced exploration of the subjects of any scientific branch makes researchers apply results of investigations and techniques of other sciences. At the same time, rapid increasing of knowledge amount and its permanent renewal requires knowledge compression and concentration (especially in educational context). So, these two opposite ways objectively influence each other, and stimulate new integration processes in the areas of scientific cognition.

Finally, in order to grasp the impact of the integration processes in science on the design of the learning content in university education, we distinguished basic aspects in which knowledge integration is expressed in scientific branches. It is necessary to emphasize that the fundamental science, as a result of people's cognition and research, in natural way depicts real-life interactive processes. Another aspect of expression of knowledge integration in science is the intersection and even merging of inquiry subjects which results in formation of unified conceptual categories, as well as of complex methods focused on the cognition of the same inquiry subject but from the standpoint of different disciplines. Besides, knowledge fusion in science is characterized by the phenomenon of disciplinarity and interdisciplinarity. It happens when a scientific branch in the process of its object investigation discovers those characteristics of the object which are also explored by other disciplines.

Thus, we obtained core theoretical basis of scientific knowledge mutual penetration in scientific branches. It allowed us to determine components of a scientific discipline in which knowledge integration must find its reflection and embodiment. These components are: unified conceptual mechanism; universal methodology of cognition; universal means of information finding out and processing; integrative cognition strategies which reflect principles of natural accordance. Using this conclusion and basing on the studies (Wagner, 2010; Wellman & Gelman, 1992; Lupu, 2015; Dufresne, Mestre, Thaden-Koch, Gerace, & Leonard, 2005; Singh & Kumar (2017), and others) we investigated the scientific discipline transformation into curriculum subject and the problem of preserving and spreading links between scientific knowledge when scientific branch gets into educational content, and when scientific knowledge become pedagogical knowledge.

As a result, we founded that the didactic component at any curriculum discipline (besides common well known tasks on adapting the learning material, selection of proper teaching aids and methods etc.) has to provide the sequence of special steps which may allow to reflect the integrative connections in proper way. So, it is necessary (1) to analyze the curriculum discipline's features and its integrative potential; (2) to reveal its contribution into fundamental general-scientific notion mechanism; (3) to find out relevant models of knowledge representation (or their combination) which enable to express interdiscipline connections; and (4) to perform knowledge penetration between the disciplines via all their components.

These steps, in fact, can provide necessary mechanisms of scientific knowledge integration in the curriculum disciplines.

2.2 Technology of integrated curriculum design based on scientific knowledge penetration

The steps determined above were put into the basis of the technology which has to be implemented for modular structuring of disciplines with the aim of performing knowledge penetration. This technology was elaborated by us resting on the concepts of the multilevel approach to the formation of vocational education content that was achieved due to different levels of knowledge generalization in its cybernetic context (Gryzun, 2013). As a mathematical tool of the technology realization we applied well known models of knowledge representation. Exactly, there were implemented semantic nets and frame-based models with their hierarchy and inheritance properties which flexibly allow providing proper links between elements of knowledge (Quillian, 1968; Minsky, 1975).

So, the technology embraces four core stages which correspond to the levels of the educational content formation (and, consequently, the levels of knowledge generalization). Each of the stages must provide the chain of analytical and practical steps, presented in details in our previous papers and covered in brief below.

The first stage of the discipline structuring starts on the “superdiscipline” level of the building of trainee’s education content. The “superdiscipline” matter is formed as a net of concentrated portions of knowledge which represents the base of expertise of pre-service specialists and provides them with perceptual unity of reality. These portions of crucial knowledge (below - PKn_s) are determined from the comprehensive analysis of contemporary requirements to the teacher; their vocational level; the essence of their activity and job scope etc. On the subsequent levels of the education content building, the discipline modules are concentrated exactly around the PKn_s (Fig. 1) of the first level.

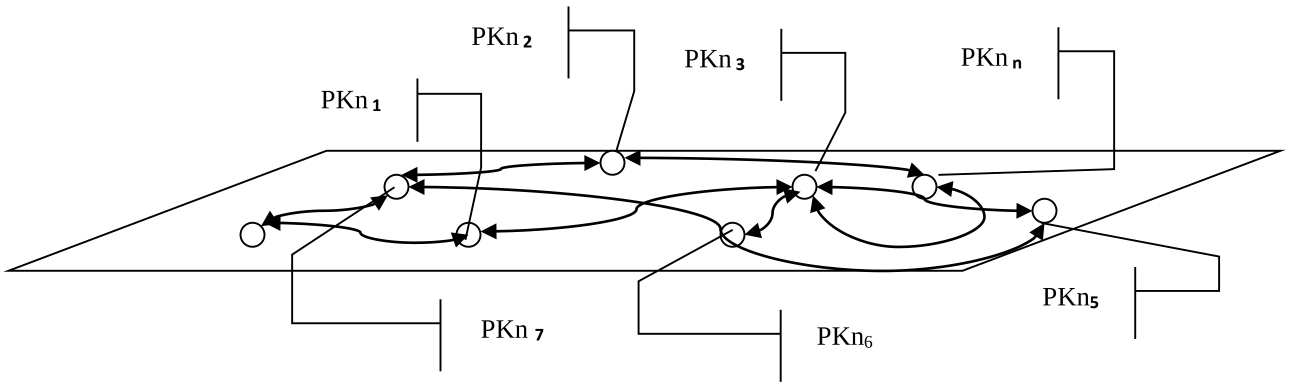

Figure 1: The net of concentrated portions of crucial knowledge presenting the first stage of the discipline structuring on the "superdiscipline" level of the building of trainee's education content

The distinguishing of the modules and their filling in with learning material of the discipline, which is structured according to the rules of frame-based model of knowledge representation, take place on the next two stages of the discipline structuring and levels of education content building. Here comprehensive didactic analysis of the discipline (as an embodiment of the scientific branch (es) and the mean of education content realization at the same time) is held. It includes proper investigation of the subject domain where it is recommended to use relevant software for subject area analysis (for instance, TextAnalyst, Textus Pro and similar to them).

Then necessary Artificial Intelligence procedures are applied. The revealed elements of knowledge are grouped around the PKn_s of previous level of the content formation. The proper connections between them are set and distributed due to built-in properties of frame model of knowledge representation (Minsky, 1975). In such a way we build hierarchical constitution, where connected frames-prototypes with inherited links (using Artificial Intelligence terms) represent the cycles of pre-service specialists' training, curriculum disciplines, and distinguished modules with the revealed elements of knowledge called on this level learning elements (LEs). Applying similar procedures to the curriculum disciplines of all cycles of vocational training, we can obtain the coordinated and coherent system of the disciplines that provide vocational training. Schematically and fragmentary it is presented as a set of linked tables (Fig.2).

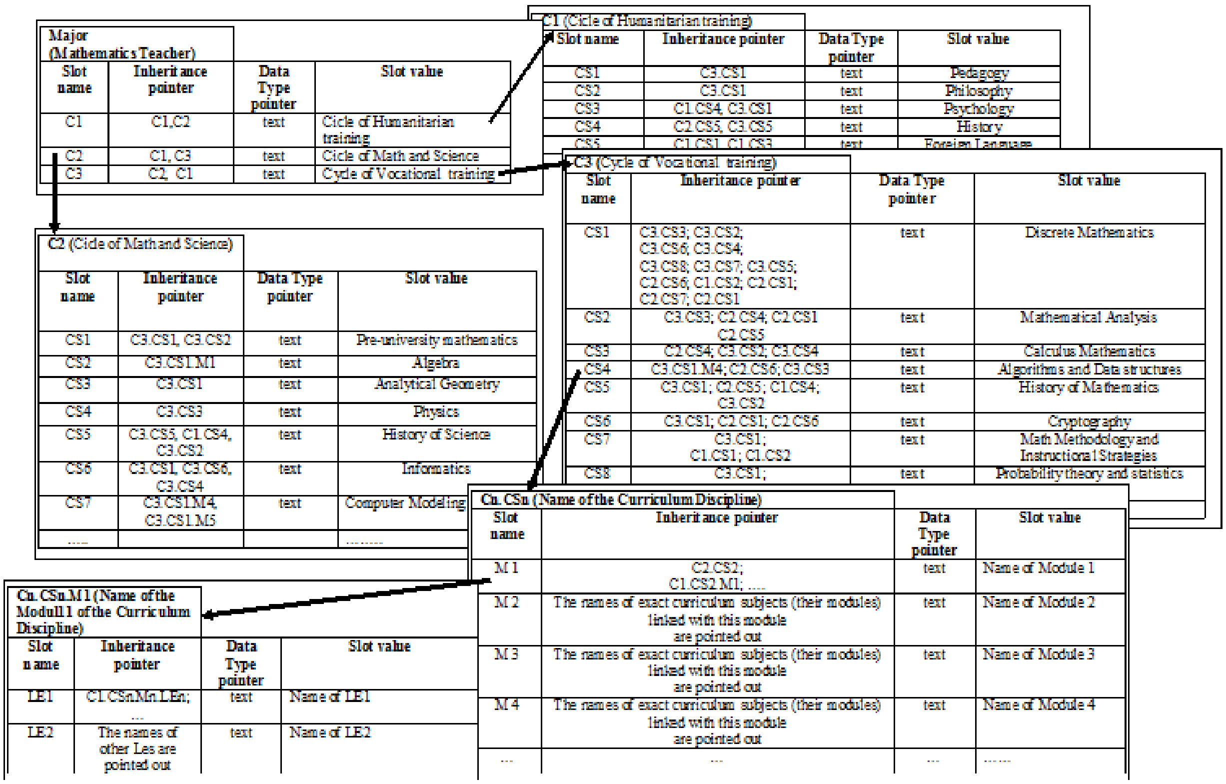

Figure 2: The part of the coordinated and coherent system of the disciplines that provide vocational training. Schematic and fragmentary presentation

The received modular structure of the curriculum disciplines contributes to keeping and spreading references between elements of knowledge inside each module and between curriculum modules. On the other hand, we also obtained entire system of disciplines compliant to the social needs and changes reflected on the highest ("superdiscipline") level. It is important to emphasise that such flexibility and entity became possible due to properties of frame model of knowledge representation, and were automated with appropriate software (within MS Access environment). It gives additional opportunities to detect immediately links between learning elements, calculate degree of knowledge infiltration, optimise sequence and coherence of learning etc. Thus, developed by us technology of curriculum disciplines structuring can provide scientific knowledge penetration within the university curriculum.

However, the elaborated integrative approach to the discipline structuring must be verified and the quality of the obtained structure has to be estimated before its implementation. Therefore, we elaborated the system of criteria which allows to evaluate if the structure of curriculum disciplines really meets the set of requirements. These requirements follow from the essence of our activity on each stage of structuring (discussed above) and must include evaluation of (1) dynamics and flexibility; (2) structureness and completeness; (3) multilevelness of knowledge generalization; (4) integrative abilities of the curriculum discipline structure. The system of quotients for each of requirements was created. So, on the whole, the criteria field for the technology expertise contains these core characteristics of obtained curriculum discipline structure: quality of selection and generalization of vocational knowledge, skills, the essence of activity of the pre-service specialists etc.; level of its adaptivity to the social demands as for vocational education; level of its coherence with other disciplines; quality of didactic analysis of the discipline; logics of selection of learning elements; logics and quality of established links between knowledge on different levels of knowledge generalization; correctness of grouping the learning elements around the portions of knowledge defined on the "superdiscipline" level. For each of the quotients we also determined the evaluation scale, which reflects five levels of the quotients' displaying.

Thus, the expertise according to the elaborated system of criteria allows to reveal drawbacks and defects, that may have happened on earlier stages of the discipline structuring and to eliminate them before the subsequent use of the obtained discipline structure. However, the final conclusion as for the efficiency of the technology should be made basing on the investigation of its influence on the results of pre-service specialists' training.

3. Methodology

The empirical research on purpose, mentioned above, was done for over 200 students (potential secondary school teachers) of national pedagogical university, Kharkiv, Ukraine. Necessary criteria system was formed basing on some core reasons. According to its aims and technological essence presented above, the integrative approach to the curriculum and content desgn may promote: (1) faster and full knowledge reflection in trainees' minds as well as re-direction of acquired techniques of activity from one curriculum subject to another, from learning activity into vocational one; (2) increase of functional links quantity in the area of integrative knowledge; (3) effective creation of links between concepts; (4) efficient satisfaction of personal cognitive needs. Thus, the quotients that can display the formation of pre-service teachers' holistic supple system of knowledge and skills, including their formed ability to promote the creation of such a system in their potential pupils' minds, must be trainees' knowledge characteristics (depth, pliability, and systemacy) and their cognitive activity.

On the preparation stage of the empirical research there were analyzed current curriculum and disciplines syllabus of the pre-service economics teachers'; the technology of disciplines structuring, based on the scientific knowledge integration, was applied to specific disciplines; the obtained modular structures of the disciplines with all determined and spread links were used as a basis of subsequent teaching and learning activity, which was elaborated for each learning element of each module.

There was also developed the system of complex tests for measuring students' knowledge characteristics (depth, pliability and systemacy) and the program of study of their cognitive activity. In order to detect the formation level of students' *knowledge depth* we included into the complex tests the tasks that allow to determine student's comprehension of the main connections between components of knowledge. There were expected four formation levels of knowledge depth: high level (revealing and understanding by a student all connections), normal level (more than half of connections), mean level (less than half of connections), low level (no connections or a few).

On purpose of measuring the formation level of students' *knowledge pliability* we elaborated the tasks which expected various ways of their solving as well as applying knowledge in non-typical situations. For each right way of solution a student could obtain one mark. Then we determined knowledge pliability quotient (KPQ), which is a ratio of obtained marks and greatest possible number of marks. There were again expected four formation levels of knowledge pliability, according to the KPQ: high level (KPQ is 1-0.75), normal level (KPQ is 0.74-0.5), mean level (KPQ is 0.49-0.25), low level (KPQ is less than 0.25).

As *knowledge systemacy* expects formation of structure-logical and functional links between dissimilar elements of knowledge in students' minds, we found relevant to include into the system of control tests the task on creating structure-logical diagram of a specific issue. The task is estimated as for the correctness of diagram nodes (knowledge components), reflected by a student, and logic of links between nodes. There were also expected four formation levels of knowledge systemacy.

In order to investigate the formation of students' *cognitive activity*, we determined the system of criteria, their indicators and techniques of their detecting, according to which it is possible to determine the kind (realized constructive, realized reconstructive, realized executive, or unrealized) of the formed student's cognitive activity. It was elaborated special monitoring program which allowed us to learn the students' expressions of the criteria and their indicators during both curricular and extra-curricular studying. The monitoring program included investigating of the indicators of students' cognitive activity: (1) raising queries and their kinds (clarifying, explaining, in-depth queries regarding the essence and establishing connections between components of knowledge etc.); (2) desire to reveal their knowledge and its way (answering questions, resolving typical problems, demonstrating original method of problem solving, in–depth remarks to other's answers, applying knowledge from additional resources); (3) enterprise (eagerness and readiness to solve problems including optional ones, knowledge using in various contexts, conscious choice of optimal and productive activity to get positive results); (4) endurance of cognitive initiative (permanent revealing of cognitive activity); (5) student's behavior regarding difficulties (giving up doing the task, asking for help and going on doing the task, going on attempts to overcome the difficulty independently); (6) addressing additional and optional learning resources (occasionally or regularly); (7) taking part in extra-curricular cognitive activity (episodically, voluntarily but episodically, voluntarily and regularly).

The scale of indicators detecting was offered. According to it we could determine the kind of student's cognitive activity: realized constructive (25-21 marks), realized reconstructive (20-15 marks), realized executive (14-11 marks), unrealized (10-5 marks).

Then there were formed experimental and control groups of pre-service teachers (108 students each one). Their knowledge characteristics and cognitive activity were measured, and it was proved (with nonparametric statistical methods) that the groups' statistical difference from the standpoint of the criteria quotients is not significant. The control group (CG) of pre-service teachers studied the set of curriculum subjects structured according to the common approach.

4. Results and Discussion

The experimental group (EG) was exposed to studying the curriculum disciplines structured using author's technology depicted above. Resting on the obtained structure of each module of the disciplines, we analyzed LEs of the modules along with the established links, and determined their particular didactic aims. Then we projected students' cross-disciplined learning activity, necessary for achieving the aims, and defined methods and forms of teaching. In particular, with the help of automatically revealed links, we could pick up proper questions and tasks (for instance, on computer dynamic modeling) that encouraged students to apply their knowledge from previous modules (courses) or emphasized the importance of the current matter for mastering other disciplines, modules, learning elements, real-life problems, etc. Besides, it enabled to formulate and offer students long-term problems and projects. They had direct interdisciplinary context and stimulated establishing practically oriented links between knowledge in trainees' minds.

During classes there were applied mostly common teaching methods. In particular, there were used reproductive method (which is based on the memorization and reproduction of students' knowledge to form their skills); problem exposing method (when the teacher step by step exposes the problem, encourages students to formulate a hypothesis, discusses contradictions with them, describes ways of thinking etc.); exploration method (which promotes creative use of knowledge by the students and implementation of research techniques) and others. These typical and well known teaching methods were applied in different combinations due to the whole aim of the module and particular aims of its LEs. However, they were used under special circumstances, exactly - at teaching disciplines which were structured basing on the scientific knowledge integration. So, the integration potential of the disciplines was reinforced both by the structure of the curriculum subjects and by the teaching methods along with cross-disciplined learning activity.

On the final stage of the empirical research all criteria quotients in both groups were measured and compared again.

It is detected that the difference of average growth of students' number of EG and CG, who have high level: of knowledge depth is 11.3%; of knowledge pliability is 11.0%; of knowledge systemacy is 7.4%. Additionally, it is found that the difference of average growth of students' number of EG and CG, who have normal level: of knowledge depth is 6.6%; of knowledge pliability is 19.4%; of knowledge systemacy is 3.9%. The results from Pearson's chi-squared test indicated that the detected difference was significant ($p = 0.05$, $df = 4$).

It is also detected the increase of students' cognitive activity. In particular, the difference of average growth of students' number of EG and CG, who display realized constructive kind of cognitive activity is 10.6%, and realized reconstructive kind of cognitive activity is 8.0%. Moreover, it is observed the 20.1% decrease of EG student's number, who reveal unrealized kind of cognitive activity, whereas in CG this decrease makes 10.2%. The results from Pearson's chi-squared test indicated that the detected difference in students' cognitive activity was significant ($p = 0.05$, $df = 4$).

Thus, the empirical research demonstrated positive impact of the elaborated technology of integrated curriculum design, based on scientific knowledge penetration, on the outcome of the pre-service teachers' training.

5. Conclusions

5.1 Resume of the research

Based on the theoretical and practical results mentioned above, the conclusions are as follow. First, integrative processes in science, contemporary demands to vocational education and increasing requirements to the level of pre-service teachers' training testify necessity of development of the approaches to discipline structuring in the process of educational content design, based on scientific knowledge integration.

Second, focusing on the concept of scientific knowledge integration and its reflection in scientific areas, there were determined proper steps that must be carried out to provide necessary mechanisms for knowledge penetration in the disciplines of university curriculum.

Third, in order to make these mechanisms function there is elaborated the technology of curriculum disciplines structuring and modules distinguishing, that allows to keep and spread references between knowledge throughout modules and disciplines. Due to applying appropriate models of knowledge representation and their properties to all the stages of the technology, there is obtained entire and flexible system of subjects, which is compliant to the social needs and changes of the curriculum, situation on labour market etc. On the other hand, the process of learning subjects structured, according to the integrative technology, contributes to the formation of students' holistic flexible system of knowledge and skills.

Multistage character of technology procedures causes necessity of its verification and the estimation of the quality of the obtained disciplines structure both before and after its introducing into practice. It is determined the system of criteria and their quotients allowing (during the preliminary expertise) to evaluate if obtained structure of curriculum discipline really meets the set of requirements.

Fourth, the final conclusion as for the efficiency of the technology was made basing on the investigation of its influence on the outcome of pre-service teachers' training. The empirical research, done on this purpose, demonstrated positive results.

Our observations and tests during empirical research showed that the combination of typical teaching methods (reproductive, problem exposing, exploration etc.) and forms of cross-disciplined learning activity, on condition of their use at teaching disciplines structured basing on the scientific knowledge integration, caused the students' relevant associations, contributed to the forming of students' generalized knowledge and skills, created conditions for their flexible applying to mastering the discipline and other subjects related to this one. Thus, in such a way the mechanisms of knowledge integration (determined in 2.1) found their complete realization. They provided mutual infiltration of related curriculum disciplines via all together: interdisciplinary notion system, cross-discipline cognitive activity, and the structured content of disciplines.

The results of the empirical research also proved efficiency of the integrated curriculum design based on the scientific knowledge penetration, and its positive impact on the outcome of pre-service teachers' preparation. In particular, it was detected its positive influence on the creation of trainees' integral flexible system of knowledge and skills, which is proved by the increase of their knowledge depth, pliability and systemacy as well as their cognitive activity.

5.2 Scope of Future Research

On the basis of these conclusions, there may be formulated the scopes and suggestions for the follow-up research. As the proposed technology enables to detect, establish and spread links between learning elements, to calculate degree of knowledge infiltration, to optimise sequence and coherence of learning, and to realize, as a result, integration mechanisms among scientific knowledge, it seems to be applicable to resolving the set of didactic problems of vocational education. In particular, it can help to form students' system of compressed knowledge which is ready to be applied to related professional areas. So, it is prospective to go on research in this branch, as well as in the branch of reasonable compression of academic time.

Besides, it is beneficial to use author's technology of curriculum design and its results for (a) building individual educational programs meeting personal and social demands; (b) detecting the equivalence level of relative majors; (c) development of knowledge base for assessment systems and efficient tests creation; (d) creating effective STEM and STEAM content; (e) automatic control of cognitive processes in education, and others. It may contribute to facilitation of professional mobility, various forms of education services delivery and provision.

Finally, it is recommended to apply the represented technology of subjects structuring to the development of the systems of Intelligent Adaptive Learning. In particular, it should be employed for the creation of the core component (so called, Modular Curriculum) of the systems as it enables students to get their own flexible structure of integrated knowledge depending on their previous level and experience, and provide them with a basis for their future education path.

5.3 Research limitation

Pointing out the research limitation it is necessary to emphasise that the determined procedures for scientific knowledge integration in the university curriculum and elaborated author's technology of the procedures realization in the process of curriculum subjects structuring and interdisciplinary curriculum development, may be successfully applied to the theory and practice of any branches of vocational training (not only in pre-service teachers' training). However, the criteria system for investigation of the technology impact might include different set of quotients for different groups of pre-service specialists. In addition, more flexible scale for the quotients measuring may be offered (for example, applying fussy logic methods), which is the prospect of further research.

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